FIG. 6 is a cross-sectional view of a low-profile tensioner bearing upon an annular member to perform a tensioning operation while the annular member is expanded to relax its interference fit with a shank member.

FIG. 7 is a cross-sectional view of an annular member having a plurality of grooves along its bore and having seals at opposed ends of the bore.

FIG. 8 is a sectional view of a tensioning apparatus being powered by a single source of high-pressure fluid selectively fluidly connected to the annular member and/or to the tensioner through valves.

FIG. 9 illustrates a method of tensioning a shank using the system of FIG. 8.

FIG. 10 is a schematic illustration of a tensioning system using an oil/water converter.

FIG. 11 is a plan view of a shank and annular member illustrating the locations of fluid passageways.

DETAILED DESCRIPTION OF THE INVENTION

The term "shank member" when used herein is meant to include elongated tension members such as bolts, studs, rods and the like whether or not they include an integral head or threads. A shank member has opposed ends, with each end having a mechanism for applying respectively opposed forces across a joint to produce a tension load in the shank. Such mechanisms may include an integral head or threads for threaded connection with a threaded nut. The term "nut" when used herein is meant to include an annular member defining an opening for receiving a shank member. The term nut is generally used in the art to denote an annular member having threads formed on its inside surface for threaded engagement with a shank member. However, in the present application, the term nut may also be used to denote an annular member having no threads on its inside surface, but rather being engaged with a shank member by an interference fit.

FIG. 1 illustrates a tensioning apparatus 10 including a shank member 12 and an annular member 14. The annular member 14 has an unthreaded inside surface 16 defining an opening 18 for receiving the shank member 12, with the opening 18 being sized to provide an interference fit connection between the shank member 12 and an unthreaded critical diameter portion 36 of the annular member 14. The shank member

12 functions as a stud and the annular member 14 functions as a nut because it grips the stud to transfer a tensile force across a flanged joint (not shown). However, the shank member 12 and annular member 14 lack the mating threads that are normally found in a typical prior art stud/nut arrangement. Rather, the interference fit between the shank member 12 and the annular member 14 provides sufficient friction for resisting relative motion there between when the shank member 12 is placed into tension between the annular member 14 and a threaded nut 30 on an opposed side of the joint.

In order to facilitate a flange tensioning process using the tensioning apparatus 10, a means is provided for conveying fluid pressure into the opening 18 to selectively expand the annular member 14 to relax the interference fit, thus selectively allowing relative motion between the annular member 14 and the shank member 12 while the shank member 12 is being pre-tensioned. One such means is illustrated in FIG. 1 as a fluid passageway 20 formed through the annular member 14 from an outside surface 22 of the annular member 14 to the inside surface 16. As can be seen most clearly in the expanded view provided in FIG. 2, fluid passageway 20 includes a hole 24 formed from the outside surface 22 to the inside surface 16 and a groove 26 formed along the inside surface 16 to be in fluid communication with the hole 24. The hole 24 is connected to a supply of pressurized fluid. Groove 26 extends 360° around the circumference of opening 18 to apply the fluid pressure evenly around the circumference of the inner surface 16. One or a plurality of interconnected grooves 26 may be formed along the inside surface 16 to direct the fluid pressure across an appropriate area of the inside surface 16 so that the annular member 14 may be selectively expanded an amount sufficient to allow movement along shank member 12 without creating unacceptably high stress concentrations within the annular member 14 or shank member 12. In one embodiment, groove 26 may be formed in a single plane lying generally perpendicular to the axis of the shank member 12. In another embodiment, the groove may have a spiral shape deviating somewhat above and below such a plane at various points about the circumference of the inside surface 16. Alternatively, as illustrated in FIG. 11, two spaced apart circumferential grooves 260 may be joined by a helical shaped groove 262 formed on the inside surface 264 of the annular member 266, with the fluid pressure being supplied either through a hole formed in the annular member or through

a longitudinal hole 268 in fluid communication with a radial hole 270 and mating outside surface groove 272 formed on the shank member 274.